7. PERSISTENCE OF BRINE IN SEDIMENTS

Another approach to evaluating the fate of the magnesium chloride brine is to assess the presence of the brine in sediments. Brine increases the salt content of the surficial sediments. This can be identified indirectly by looking at the electrical conductivity of the sediment, or directly by collecting samples of the sediment and analyzing for soluble ions. This section discusses evaluation of the sediment for brine contamination.

7.1   Ground Conductivity Survey

In 1992, ground-based magnetic and electromagnetic induction geophysical surveys were conducted at the SDA to provide information on contrasts in ground conductivity (Ebasco Environmental Corporation 1993). These contrasts can arise from buried metallic objects, but also from changes in moisture content, mineralogy, and the salt content of pore water. The primary objective of the geophysical surveys was to identify locations where waste was buried. The penetration depth of the electromagnetic survey at the SDA was approximately 20 ft. Figure 32 shows a map of the electromagnetic quadrature phase from the 1992. Data used to generate this map were collected in the spring and fall of 1992. Because brine was applied in the summer of 1992, the time when data were collected may be important. Most of the western end of the SDA was surveyed from March to May (spring) of 1992. The east end of the SDA was surveyed in November and December (fall) of 1992. Three areas, an area along the southern boundary, an area in the north central portion of the SDA, and a small area just east of Pad A, were surveyed in both the spring and fall.

Most of the anomalous elevated ground conductivity shown in Figure 32 can be attributed to metal in buried waste. However, there are a number of areas with moderate (green shading) to high (yellow shading) conductivity that appear to be related to roads rather than buried waste because these anomalies parallel the roads. Just inside the eastern entrance to the SDA along the main east-west haul road is an area (identified with a white ellipse "A") where extended bands of very high conductivity parallel the road. Further west along the haul road, west of Pad A at "B" and south of Pit 13 at "D", are other areas where bands of elevated conductivity parallel the roadway. Just west of the active pit area, the roads tend to have moderate (green shading) ground conductivity while the surrounding sediments are low (blue shading) conductivity ("C" and "E"). Near the midpoint of the southern SDA boundary is a road that exits the SDA. This roadway is another area where the roadbed appears to have elevated conductivity not related to buried waste ("G"). At the west end of the SDA, the ground conductivity under the main haul road is very high (red shading), suggesting the road crosses over buried waste. Just inside the west entrance gate to the SDA ("F"), there is an area where the roadbed shows moderate ground conductivity. The electromagnetic induction survey of these roads was conducted in the spring of 1992, seven years after the previous application of brine to SDA roads in 1985. This suggests a persistence of brine in the roadbeds over extended periods of time.

Conductivity anomalies in the SDA are dominated by buried waste, but may also be related to moisture content or pore-water salt content. The roads in the SDA appear to have a moderately elevated ground conductivity relative to the surrounding sediment. Most of these data were gathered seven years after brine application, suggesting that magnesium chloride is persistent in the SDA roadbeds. Bands of elevated ground conductivity along roadways are related to drainage ditches. These bands may indicate salt buildup along roads, but could also be related to elevated moisture content in the ground beneath drainage ditches. Analysis of sediment samples for soluble ions could help answer this question.
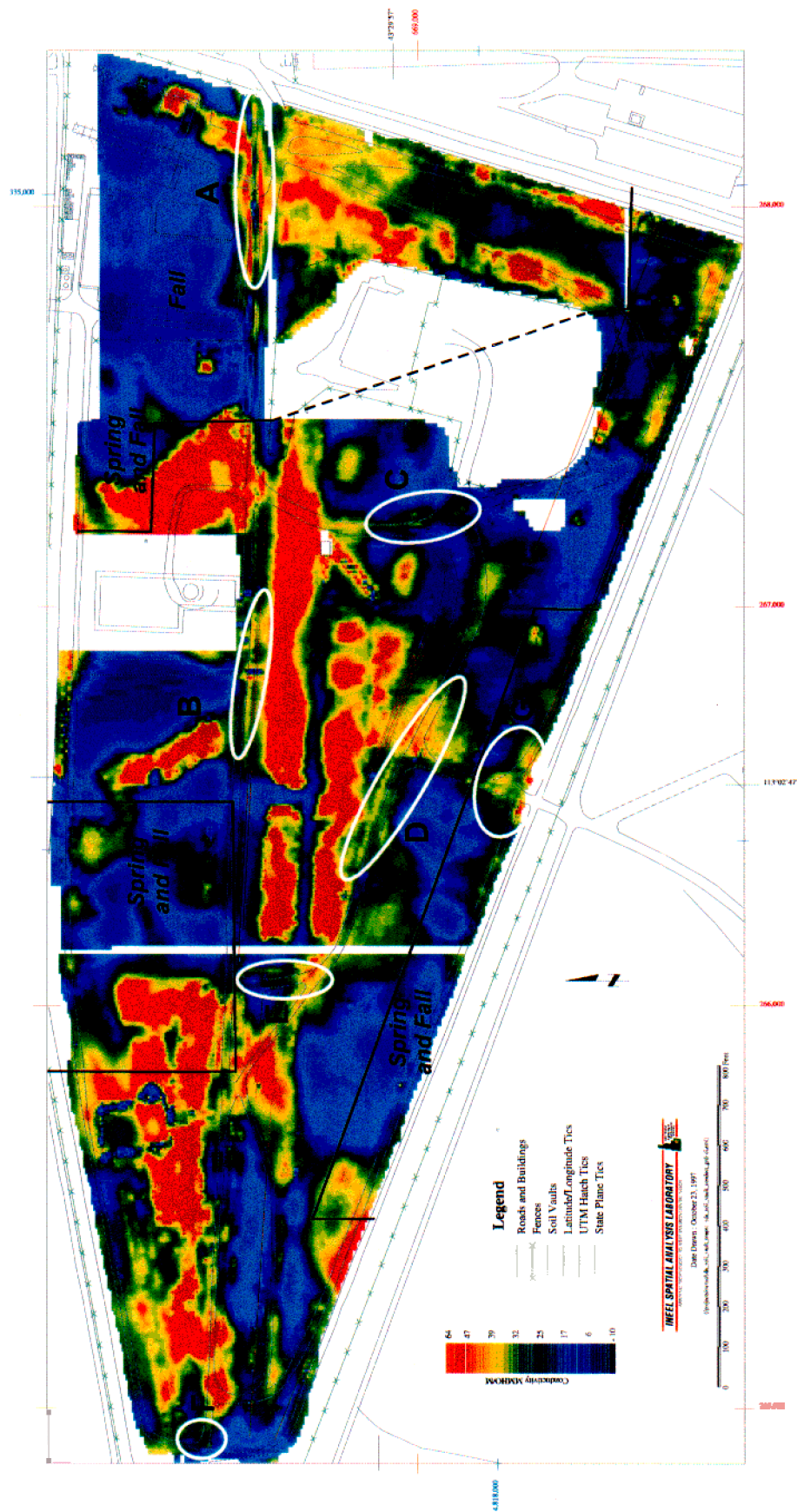
Figure 32. Map of sediment conductivity of the SDA measured in 1992 using electromagnetic induction.

7.2   SDA Surficial Sediment Samples

A number of areas inside the SDA with elevated ground conductivity were associated with roads, which suggests that brine might persist for years in the SDA. To evaluate whether elevated conductivity anomalies in roadbeds and drainage ditches along roads are related to brine, sediment samples were collected and analyzed for soluble cations and anions as a method to test for brine persistence. Twelve boreholes were augered through the surficial sediments to basalt. Split-spoon samples of sediments were collected through the hollow stem auger. Additional samples of surficial sediment were collected from archived core stored in the INEEL Core Library from past drilling in the SDA. Selected sedimentary material, taken from the Core Library, was sampled for three additional wells. This provided older sample material from locations near where the new wells were drilled. This material provides a comparison between time intervals. Samples were also collected of Spreading Area B (SAB) sediment, which has not been contaminated with brine, to provide background concentrations of soluble salts.

7.2.1   Site Selection

Because the objective was to evaluate persistence of chloride in SDA surficial sediments, and to evaluate the potential for lateral movement of the brine from the roads to buried waste, borings were located where:

- Geophysical measurements indicated elevated levels of ground conductance associated with roads

- Chloride contamination in suction lysimeters indicated brine migration and persistence.

Ground conductance, Figure 32, was used to identify locations where the sediment was moderately to highly conductive along roads where brine was applied. The ground conductivity map reflects all contributing sources to anomalous conductance including the salt content of the sediment, the moisture content of the sediment, and the presence of buried metals. Much of the very high and high conductivity areas shown in Figure 32 reflect buried waste. As discussed earlier, there were a number of locations where moderate- to high-conductivity anomalies seemed to be associated with roads, and not with buried waste. These areas were identified for sampling. Suction lysimeters in the southeast corner of the SDA contained very high levels of chloride and sulfate, indicating brine contamination. Therefore, this southeast corner was also identified as a target area for sampling.

Figure 33 shows the locations of the twelve auger holes drilled to collect samples, as well as the locations of the three older wells from which core was analyzed. Borings were drilled in January and February 1998. Lysimeters were installed in five of these holes after sediment samples were collected. Core collected from three wells drilled between 1986 and 1990 was also sampled. Spreading Area B is a playa west of the SDA. Sediments in the playa were deposited in a similar depositional environment to that in the SDA. Playa sediments from Spreading Area B were not contaminated with brine, and so were sampled to provide comparable background concentrations of extractable salts for SDA sediments.

In the southeast corner of the SDA, boring 98-1 was drilled near a buried beryllium block that is being investigated as a source of carbon-14 and tritium (Ritter and McElroy 1999). Elevated chloride concentrations in this area, as identified from lysimeters in wells W05 and LYS-01, may be contributing to the corrosion of the beryllium. Sediment from well W05, drilled in 1986, was available in the Core Library, and samples were collected from this core to compare with core from boring 98-1.

Near the middle of the southern boundary, there is a road that exits the SDA. This road indicated elevated ground conductivity ("G" in Figure 32). Boring SDA-05 was drilled in the middle of the road, boring SDA-04 was drilled in the ditch adjacent to the road, and boring 98-2 was drilled across the ditch

from the road. A lysimeter was installed in boring 98-2. These three wells provide a profile from the middle of the road across the drainage ditch to examine the lateral spread of brine away from the road.
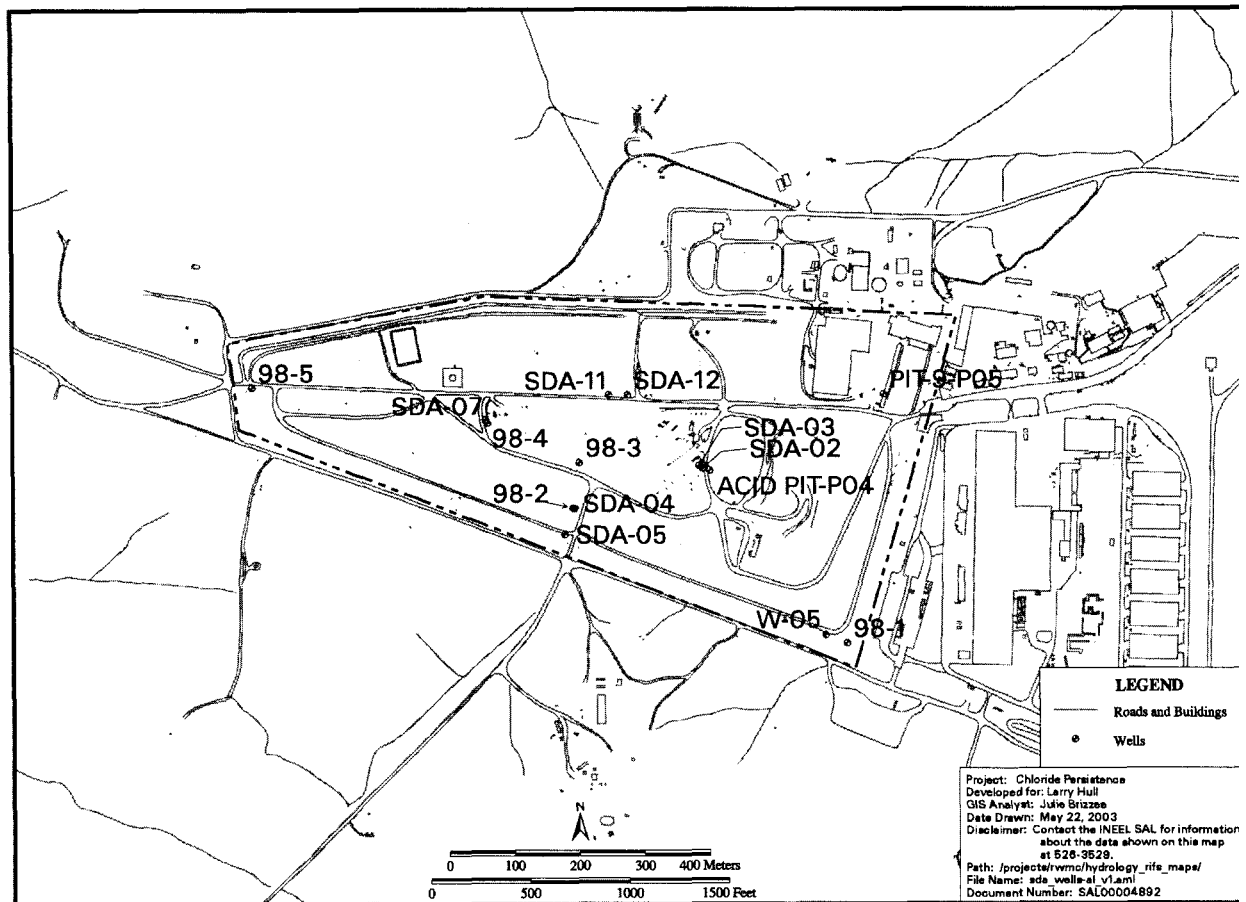
Figure 33. Map of the SDA showing the locations of wells where sediments were collected for analysis of soluble ions.

The road that leads to the active pit showed moderately elevated levels of ground conductivity ("C," in Figure 32). Two borings were made here: SDA-02 in the middle of the road, and SDA-03 in the drainage ditch along the road. Core material was available from a boring made adjacent to this road in 1990, Acid Pit #4. Samples were collected from that boring also.

South of Pit 13, high ground conductivity parallels the road ("D" in Figure 32), which could be related to brine in the sediment. Boring 98-3 was drilled into this anomaly and a suction lysimeter installed.

West of Pits 4 and 10, there was another area of moderately elevated ground conductivity in the road bed ("E"). Two borings, SDA-07 and 98-4, were drilled in this area. Boring SDA-07 was drilled in the drainage ditch along the road and boring 98-4 was drilled just behind the drainage ditch. A suction lysimeter was installed in hole 98-4. This location is also adjacent to an existing well W25. Suction lysimeters in well W25 did not show signs of brine contamination.

A series of borings was placed along the main east-west haul road, where brine was applied at least three, probably four, times. At the west end of the SDA, 98-5 was drilled beside a roadbed that showed moderate ground conductivity ("F"). A lysimeter was installed in boring 98-5. Just west of Pad A, two borings were drilled in the drainage ditch immediately adjacent to the main haul road. This area showed very high ground conductivity parallel to the road ("B" in Figure 32) in 1992. At the east end of the haul road, just inside the entrance to the SDA, existing core was taken from the Core Library for well Pit-9 #5, drilled in 1990. This well is close to well W03, which showed very high levels of chloride in lysimeter samples, and is in an area of very high ground conductivity ("A").

The locations selected for borings, or for collection of existing core material from the Core Library, provide samples from areas that show elevated ground conductivity and/or elevated chloride concentrations in lysimeter samples. Samples target drainage ditches to determine if elevated conductivity results from increased water content or high chloride concentrations. In two locations, three borings are drilled from the road to the opposite side of the drainage ditch to evaluate lateral spread of brine from the roadway. From these well locations, we will be able to assess the persistence of chloride in roads and drainage ditches, and evaluate lateral spread away from the roads.

7.2.2 **Laboratory Methods**

A total of sixty sediment samples were collected: 50 from new borings in the SDA, eight from existing core material in the Core Library, and eight from SAB sediment. The SDA samples were collected during January and February 1998; the rest were taken from archived samples stored at the INEEL Core Library. Most of the samples were clays or clay loams. The sediment samples were extracted following the procedure for soluble salts outlined in *Soil Methods and Analysis, Parr 2* (Rhoades 1982). Sediments were extracted using a ratio of 1 part sediment to 5 parts deionized water by weight. The sediment and water mixture was shaken on a shaker table for 1 hour, then filtered through a 0.45 µm filter. The extracts were analyzed for sodium, calcium, potassium, magnesium, lithium, chloride, bromide, nitrate, and sulfate. Measured concentrations in the extract were used to calculate the concentration of soluble salt in the sediment.

Five duplicate samples were analyzed, and relative percent difference (RPD) calculated using:

$$RPD = \left| \frac{(C_1 - C_D)}{(C_1 + C_D)/2} \right| \cdot 100 \qquad (2)$$

where C_1 is the measured concentration and C_D is the concentration measured on a duplicate sample. Values of RPD should fall between -20% and +20%. The average of the absolute value of the 5 RPD values for each analyte is reported in Table 10. Two individual RPD values calculated for Mg were at or above the 20% limit (one at 20% and one at 23%). All of the other calculated RPD values were well within the ±20% range.

7.3   Extractable Cation and Anion Data

The analytical results for each of the locations is given in Appendix C. Samples high in water-extractable salt for one ion tend to be high for many of the ions. Correlation coefficients for the ions show that the soluble ions with the highest correlation to chloride are bromide (0.81). magnesium (0.83), and sodium (0.86). The bromide and magnesium were components of the brine. The correlation of the three ions (Cl, Br, Mg) indicates that the elevated soluble salts in these samples are related to the brine. Sodium is likely elevated by displacement from ion exchange sites on clays by magnesium as the brine infiltrates.

41

Table 10. Average of the absolute value of the RPD for the soluble ion extractions.

Ion	Average RPD
Cl	0.9%
Br	0.1%
NO3	10.5%
SO4	0.8%
Ca	3.9%
K	6.4%
Mg	9.0%
Na	0.7%

Spreading Area B sediment, which has not been contaminated by brine, has very low concentrations of extractable ions compared to the samples from inside the SDA. The SAB sediment is used to define background concentrations of soluble salts at the mean plus three standard deviations of the eight measurements on SAB sediment. This gives a background chloride concentration of 1 mg/kg.

7.3.1   Soluble Chloride Distribution in Sediments

Three borings were drilled and sampled along the main east-west haul road, and existing core from a fourth well drilled near Pit 9 was sampled (Figure 33). The three wells drilled in 1998 show background or very low levels of chloride (Figure 34). The chloride concentrations near the surface in well 98-5 are slightly above background, indicating some brine residual in the sediment. Borings SDA-11 and SDA-12 were drilled in a location that showed very high ground conductivity in the 1992 geophysical survey. This is an area where water accumulates (Figure 3), and is an area of elevated infiltration (Martian 1995; Bishop 1998). Therefore, the high ground conductivity in 1992 may have only reflected water content. If chloride was present in 1992, then it has since been flushed from the system. At the eastern end of the haul road, in well Pit-9 #5, sediments contained elevated chloride in 1990 (when the well was drilled). This confirms water samples collected from a lysimeter in nearby well W03, which contained elevated chloride. The geophysical survey conducted in 1992 indicated very high ground conductivity in this area. Well W03, and the lysimeter therein, were destroyed by construction of the Pit 9 project. As such, there is no information from this area to evaluate current conditions.

Extractable chloride in borings drilled in the central portion of the SDA around Pits 4, 10, 13, and the Acid Pit (areas C, D, and E in Figure 32) are shown in Figure 35. SDA-02 was drilled in the middle of the road, and shows moderately elevated chloride concentrations. Well SDA-02 was drilled six years after the conductivity survey, and five years after the last brine application. Concentrations are still moderately elevated in the roadbed to a depth of 6.5 ft. Below a depth of 6.5 ft, the samples reflect background chloride concentrations. In boring SDA-03 and Acid Pit #4, both of which are drilled adjacent to the road, most of the concentrations are within background or are slightly elevated. At this location, there is little evidence of lateral spread of chloride.

Borings SDA-07 and 98-4 (Figure 33) were drilled in, and just behind, the drainage ditch. Chloride concentrations in these borings are slightly above background levels, and show chloride at all depths (Figure 35). The ground conductivity of the road here is only moderately elevated, similar to the ground conductivity at SDA-02. Borings 98-4 and SDA-07 show similar patterns to SDA-03 and Acid Pit #4. For this part of the SDA, it appears that the roadbed retains some of the magnesium chloride brine. Brine has migrated to depths several feet below drainage ditches, and laterally several feet. Concentrations in the sediment, however, are on the order of a few dozen mg/kg, which is relatively low.

Boring 98-3 was made in an area of very high ground conductivity along a roadway. Elevated chloride concentrations are apparent in the sediment to a depth of over 23 ft. This area is identified as an area where snowmelt runoff can accumulate (Figure 3), but is not an area of high recharge (Martian 1995; Bishop 1998). Chloride remains in the sediment at 98-3 some five years after brine application and is present down to the sediment-basalt interface at a depth of about 23 ft. This distribution seems to support previous conclusions that this is not an area of high recharge. In areas of high recharge along the main haul road, chloride had been flushed from the sediment by 1998 (Figure 34). Here, sufficient recharge has occurred to carry chloride to a depth of 23 ft, but not enough to flush chloride out of the sediments. Appreciable chloride remains in this location.

	Chloride (mg/kg)			
Depth (ft)	98-	SDA1	SDAI	PIT 9 #
.0 - 1.6	14.8			
.6 - 3.3	13.3	1.5	0.5	
.3 - 4.9	5.8		0.2	
.9 - 6.6	2.1			
.6 - 8.2		1.1		
.2 - 9.8	5.5		0.2	
.8 - 11.5		3.6		122.1
11.5 - 13.1				
13.1 - 14.8				
14.8 - 16.4				
16.4 - 18.0				148.6
18.0 - 19.7				
19.7 - 23.0				
Average	7.57	2.08	0.32	135.3
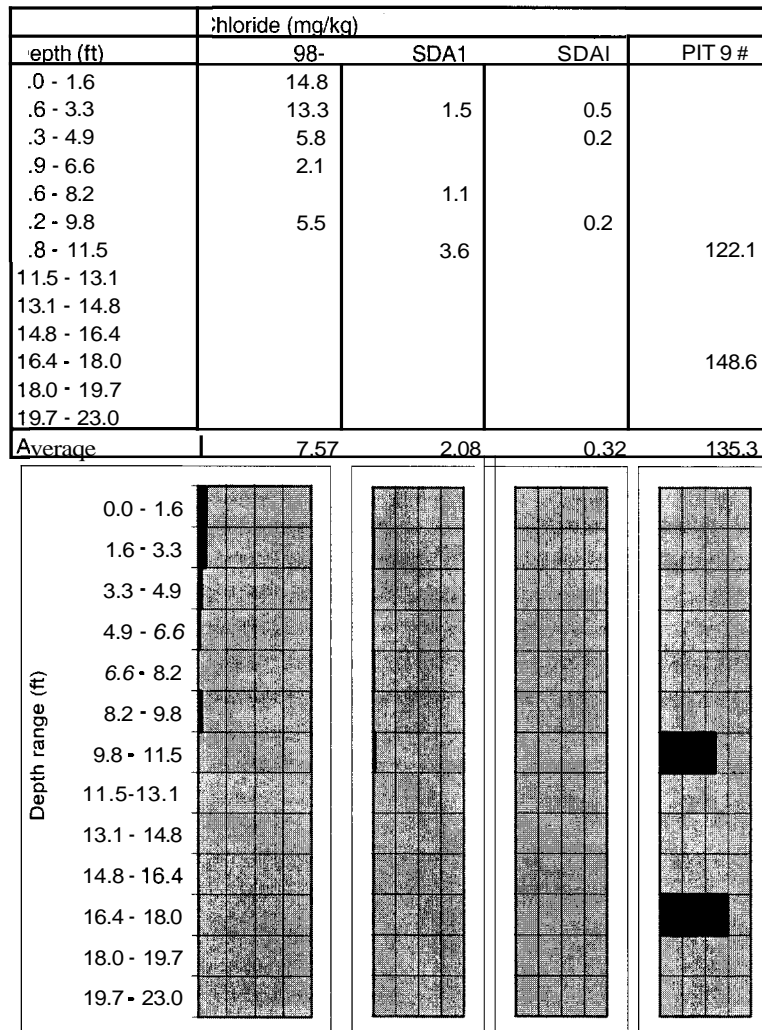
Figure 34. Distribution of extractable chloride, in mg/kg, with depth along the main east-west haul road. The scale of the graphs is 0–200 mg/kg.

43

Depth (ft)	Chloride (mg/kg)			SDA07	98-4	98-3
0.0 - 1.6			6.6:			
1.6 - 3.3						
3.3 - 4.9		170.32	34.3'	3.73	21.85	212.95
4.9 - 6.6		152.01				
6.6 - 8.2						39.30
8.2 - 9.8			1.1'	15.13	2.23	
9.8- 11.5	0.04		0.2			15.99
11.5- 13.1		1.34				
13.1 - 14.8				13.58	25.12	49.41
14.8 - 16.4	38.80	1.07		10.74	3.29	
16.4 - 18.0						
18.0 - 19.7		1.06				697.06
19.7 - 23.0						485.73
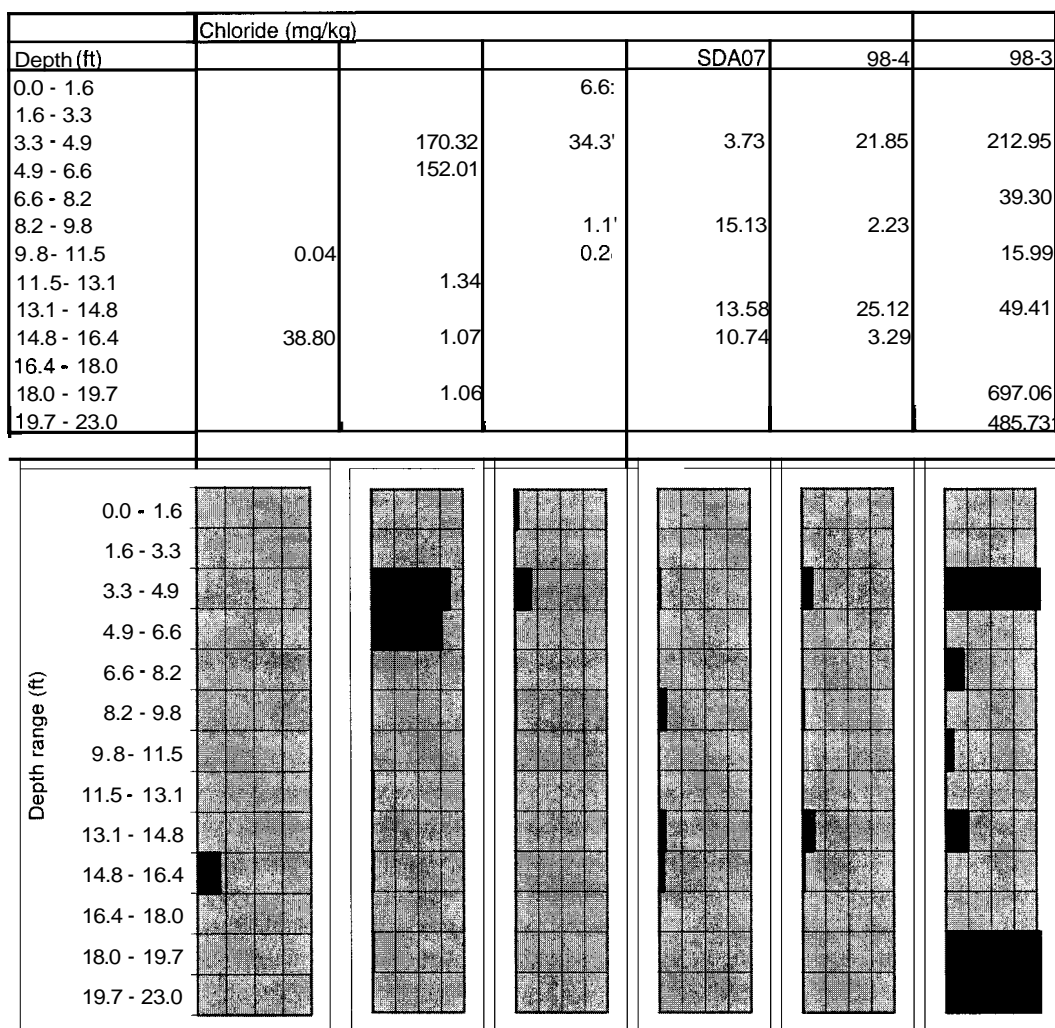
Figure 35. Distribution of extractable chloride, in mg/kg, with depth from the central portion of the SDA around Pits 4, 10, 13 and the Acid Pit. The scale of the graphs is 0–200 mg/kg. To show more detail at low concentrations, some of the higher concentrations are truncated. Information for higher concentrations is shown in the attached table.

Borings drilled along the southern boundary of the SDA show the highest levels of extractable chloride (Figure 36). The graph scale in Figure 36 is 10x the scale in the previous two graphs. Boring W05 was drilled in 1986, and boring 98-1 was drilled in 1998 in the southeast comer of the SDA. In that 12 year period, chloride appears to be migrating slowly downward. Concentrations at comparable depths in the two wells are lower in 1998, and the deeper concentrations in well 98-1 are lower than the concentrations in W05, suggesting dilution of the chloride. Concentrations are still very high, and lysimeter water samples from well 98-1 (98-1-L35) confirm that the pore water is still elevated in chloride. The lysimeter in boring LYS-1, beside the beryllium blocks, shows a 675 to 102 mg/L decrease in chloride from 1997 to 2000. Some decrease in chloride is taking place in the southeast comer of the SDA. However, significant chloride remains in the pore water and in the sediment. The persistence of chloride in pore water and sediment indicate that this is an area of relatively low recharge.

epth (m)	Chloride (mg/kg)				
	W05	98-1	98-2	SDA05	SDA04
.0 - 0.5	672		9		
.5 - 1.0					
.0 - 1.5	653	497	26	574	1035
.5 - 2.0		278	198	900	1167
.0 - 2.5					
.5 - 3.0	2123				2104
.0 - 3.5	1343				
.5 - 4.0					
.0 - 4.5		1703			
.5 - 5.0		1112			
.0 - 5.5					
.5 - 6.0					
.0 - 7.0					
verage	1093	897	78	737	1435
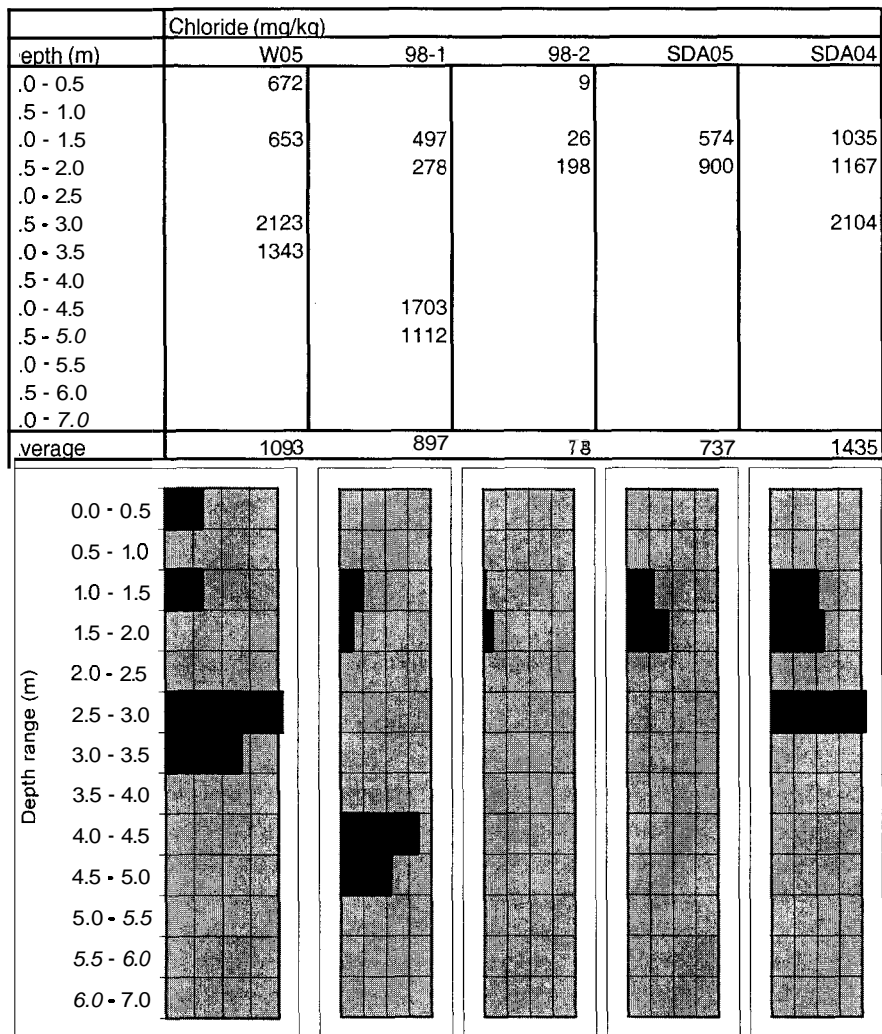
Figure 36. Distribution of extractable chloride with depth along the southern boundary of the SDA. The scale of the graphs is 0–2,000 mg/kg, or 10x the scale in the previous figures.

Near the southern exit from the SDA, the geophysical survey indicated very high ground conductivity in the road ("G"). Brine was applied to this road exiting the southern SDA boundary at least three, possibly four, times. Samples of roadbed material collected from the middle of the roadway in boring SDA-05 show that, even six years after the geophysical survey, the roadbed retains high levels of chloride. Boring SDA-04, drilled in the drainage ditch along the road, contains even higher soluble chloride than the roadbed samples. Extractable chloride in the sediments is as high as 2,100 mg/kg (Figure 36). The sediment in boring 98-2, drilled behind the drainage ditch, contains elevated extractable chloride at a depth of 5 to 6.5 ft. The concentrations are an order of magnitude less than the concentrations in the adjacent drainage ditch at SDA-04. At this location, chloride has migrated into the drainage ditch, but very little has migrated further away from the road.

7.3.2   Comparison of Soluble and Dissolved Chloride Concentrations

In a few locations, data for chloride dissolved in pore water, and chloride extracted from sediments, were gathered from similar depths in the same well. In these few cases, it is possible to compare the dissolved and extracted concentrations. Because chloride is soluble and conservative, the chloride is

expected to occur in the pore water extracted from the sediment, and so should have comparable concentrations to the chloride concentration sampled in lysimeters. In that case, the dissolved concentration can be estimated from the bulk density and moisture content of the sediments using:

$$Cl_{ex} = Cl_{dis} \cdot \frac{\theta_w}{\rho_b}$$ (3)

where:

Cl_{ex} = extractable chloride (mg/kg)

Cl_{dis} = dissolved chloride (mg/L)

θ_w = water content (1 water/L sediment)

ρ_b = bulk density (kg/L of sediment)

Bulk density and moisture content were not measured for these samples. However, many measurements of bulk density and water content have been made (Barraclough et al. 1976; Martian 1995), indicating the water content ranges from 0.2 to 0.3 cm^3/cm^3 and bulk density ranges from 1.3 to 2.0 g/cm^3. The ratio of water content to bulk density will range from 0.1 to 0.23, with an expected value in the range of 0.15. Comparable dissolved and extracted chloride data are listed in Table 11 and plotted in Figure 37. Fitting Equation 3 to the data indicates a water content to bulk density ratio of 0.157, which is well within the expected range. This provides a means of estimating dissolved chloride from extractable chloride concentrations. More importantly, it confirms that the chloride is retained in the pore water and is mobile in the SDA sediment. Where chloride is retained, it means that recharge is not taking place to flush the chloride from the sediment.

Table 11. Comparison of soluble chloride extracted from sediments and dissolved chloride collected from suction lysimeters for data collected at comparable depths.

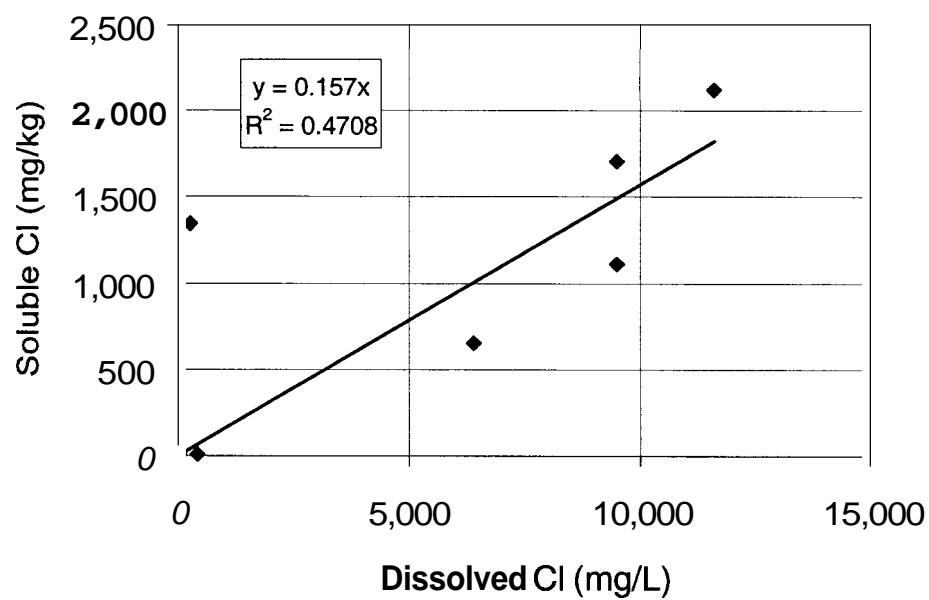| Lysimeter	Depth (ft)	Dissolved Cl (mg/L)	Well	Depth (ft)	Soluble Cl (mg/kg)
98-1-L35	16.5	9,490	98-1	15.0	1,703
98-1-L35	16.5	9,490	98-1	18.0	1,112
98-4-L38	17.0	25	SDA-07	17.5	11
98-5-L39	10.5	420	98-5	10.5	9
W05-L24	16.0	269	W05	13.3	1,343
W05-L25	10.0	11,600	W05	10.3	2,123
W05-L26	6.7	6,403	W05	6.4	653

Figure 37. Correlation between dissolved chloride and soluble chloride in **SDA** sediments.

8. DISCUSSION

Between 1984 and 1993, magnesium chloride brine was applied to roads in and around the SDA to control airborne dust. Water samples from suction lysimeters installed along roads contained very high chloride concentrations (Cl > 1,000 mg/L), suggesting that chloride might be migrating through the surficial sediment. Because chloride can enhance corrosion, information on whether chloride could be contributing to corrosion of waste containers and buried activated metals was needed. To address this question, data were needed on: 1) the locations where magnesium chloride brine was applied to roads relative to the locations of pits and trenches, 2) the distance chloride could move laterally from roads where brine was applied, and 3) whether chloride was rapidly washed out of the surficial sediments, or remained where it could continue to contribute to corrosion. The locations where brine was applied was obtained from company records. Data on the persistence and distribution of chloride were gathered using a ground conductivity survey, water samples from suction lysimeters, and soluble ions extracted from sediment samples.

Maps of brine application inside the SDA show that brine was applied over pits and trenches in four locations. Therefore, brine was applied where downward migration would bring it into contact with buried waste. East of Pit 15, brine was applied over, or very close, to a buried beryllium block. Brine was applied to roads that parallel pits and trenches in many other locations, *so* that lateral migration of chloride from the road could bring the chloride into contact with waste in additional pits and trenches.

Suction lysimeters at the SDA have been sampled periodically for major cation and anion composition since 1986. Analysis of anion data show that a significant factor affecting water chemistry at the SDA is the magnesium chloride brine that was applied to roads between 1984 and 1993. Elevated chloride concentrations were found in lysimeters along many of the roads in the SDA. Evaluating the distance from the roads to the affected lysimeters, brine was observed to migrate laterally in the surficial sediments up to 40 ft. Lysimeters and extractable ions in two wells in the south-east corner of the SDA (98-1, W05) showed significant contamination with brine. These two wells are much further than 40 ft (86 ft and 170 ft) from the closest road where brine was applied. This would require significant lateral brine migration at shallow depths (<10 ft) within three years in the surficial alluvium. Two adjacent wells (W04, W06) are not contaminated with brine. At this time, we cannot resolve the origin of the brine contamination in these two wells.

Evidence of brine has been found in lysimeters and perched water monitoring wells to depths of 240 ft. Chloride from the brine moved downwards very rapidly and was detected in a lysimeter at a depth of 100 ft in 1987, no more than three years after the brine was first applied. Estimated migration rates in the vadose zone under the SDA from brine range from a low of 20 ft/yr to a high of 140 ft/yr. The 140 ft/yr rate includes a significant lateral component (360 ft lateral, 43 ft vertical). In the surficial sediment and in the A-B interbed, chloride concentrations in suction lysimeters are returning to natural levels, indicating that the chloride is being flushed from these zones.

Samples collected from roadbeds, in wells SDA-02 and SDA-05, show that chloride has penetrated into the roadbed up to 6.5 ft, and is present in concentrations on the order of one to several hundred mg/kg. At SDA-02, where samples were collected several yards below the roadbed, the deeper samples are at background levels. Downward migration does not appear to occur rapidly under the roadbeds. Samples collected from drainage ditches along roadbeds show more vertical movement of brine contamination. Where recharge through the ditch is high, such as along the main haul road, it appears that the brine has been flushed out of the sediments (98-5, SDA-11, and SDA-12). Where recharge is less, the amount of chloride under drainage ditches is highly variable. However, in SDA-04 and 98-3, there are high concentrations of chloride in ditch sediments to depths of up to 23 ft. Where samples were collected on the side of the drainage ditch away from the roadbed (98-2, 98-4), concentrations are significantly

reduced from concentrations in the road or drainage ditch. For the most part, vertical migration of brine appears to be occurring under drainage ditches adjacent to the roads where brine was applied.

This investigation had three objectives: **1**) where and how much brine was applied to roads in the **SDA, 2)** where did the brine go in the sediments and pore water, and 3) is the brine being flushed from the surficial sediments. An estimated 660 tons of brine were applied in the **SDA** between **1984** and **1992** containing 178 tons of chloride. In four locations, brine was applied directly over trenches or soil-vault rows. One of the beryllium disposal areas was crossed by brine application. In other locations, brine was applied to roads that parallel pits and trenches. Brine penetrated the roadbeds on which it was applied to a depth of about 6.5 ft. Most brine was redistributed to the drainage ditches adjacent to the roads. Brine migration occurs under these ditches, not directly under the roads. Brine was observed to move laterally from the roads up to 40 ft, based on chloride contamination in suction lysimeters and from extractable chloride concentrations in sediments.

Extractable chloride correlates well with dissolved chloride in the few locations where sediment samples and lysimeter samples are colocated. This indicates that the chloride remains in pore water, does not partition to the sediment, and is potentially mobile. Where chloride remains in the **SDA** surficial sediments, recharge has not been sufficient to flush the chloride from the surficial sediments in that area. Chloride persistence, therefore, is an indication of low recharge in a location. Areas where chloride has been flushed from the surficial sediments correspond to areas that have been identified by hydrolic investigations as high recharge areas, confirming the hydrologic conculsions.

9. REFERENCES

Anderson, S. R, and B. D. Lewis, 1989, *Stratigraphy of the Unsaturated Zone at the Radioactive Waste Management Complex, Idaho National Engineering Laboratory, Idaho,* U.S. Geological Survey Water Resources Investigations Report 89-4065, U.S. Geological Survey, Idaho Falls, Idaho.

Anderson, S. R., M. J. Liszewski, and D. J. Ackerman, 1996, *Thickness of Surficial Sediment at and Near the Idaho National Engineering Laboratory, Idaho,* U.S. Geological Survey Open-File Report 96-330, U.S. Geological Survey, Idaho Falls, Idaho.

Barraclough, J. T., J. B. Robertson, and V. J. Janzer, 1976, *Hydrolgy of the Solid Waste Burial Ground, as Related to the Potential Migration of Radionuclides, Idaho National Engineering Laboratory,* IDO-22056, U. S. Geological Survey Open File Report 76-471, U. S. Geological Survey, Idaho Falls, Idaho.

Bartholomay, R. C., L. L. Knobel, and L. C. Davis, 1989, *Mineralogy and Grain Size of Suljcicial Sediment from the Big Lost River Drainage and Vicinity, with Chemical and Physical Characteristics of Geologic Materials from Selected Sites at the Idaho National Engineering Laboratory, Idaho,* DOE/ID-2208 1, U. S. Geological Survey Open-File Report 89-384, U. S. Geological Survey, Idaho Falls, Idaho.

Bartholomay, R. C., 1990, *Mineralogical Correlation of Suljcicial Sediment from Area Drainage with Selected Sedimentary Interbeds at the Idaho National Engineering Laboratory, Idaho,* U.S. Geological Survey Water-Resources Investigations Report 90-4 147, DOWID-22092, U.S. Department of Energy Idaho Operations Office, Idaho Falls, Idaho.

Bishop, C. W., 1998, *Soil Moisture Monitoring Results at the Radioactive Waste Management Complex of the Idaho National Engineering Laboratory, FY-96, FY-95, and FY-94,* INEEL/EXT-98-0094 1, Idaho National Engineering Laboratory, Lockheed Martin Idaho Technologies Company, Idaho Falls, Idaho.

Bowman, A. L., W. F. Downs, K. S. Moor, and B. F. Russell, 1984, *INEL Environmental Characterization Report,* Vol. 2, EGG-NPR-6688, Idaho National Engineering and Environmental Laboratory, EG&G Idaho, Idaho Falls, Idaho.

Case, M. J., A. S. Rood, J. M. McCarthy, W. O. Magnuson, B. H. Becker, and T. K. Honecutt, 2000, *Technical Revision of the Radioactive Waste Management complex Low-Level Waste Radiological Performance Assessment for Calendar Year 2000,* INEEL/EXT-2000-0 1089, Idaho National Engineering and Environmental Laboratory, Bechtel BWXT Idaho, LLC, Idaho Falls, Idaho.

Chatwin, T. D., A. D. Coveleski, K. J. Galloway, J. M. Hubbell, R. M. Lugar, G. E. Mathern, O. R. Perry, A. J. Sondrup, and S. N. Stanisich, 1992, *Final Work Plan for the Organic Contamination in the Vadose Zone, Operable Unit 7-08, Focused Remedial Investigation/Feasibility Study,* EGG-WM-10049, Idaho National Engineering and Environmental Laboratory, EG&G Idaho, Idaho Falls, Idaho.

Clawson, K. L., G. E. Start, and N. R. Ricks, 1989, *Climatography of the Idaho National Engineering Laboratory,* 2nd ed., DOE/ID-12118, U.S. Department of Energy Idaho Operations, Idaho Falls, Idaho.

Dechert, T. V., P. A. McDaniel, and A. L. Falen, 1994, *Aggradational and Erosional History of the RWMC at the INEL,* EGG-WM-11049, Idaho National Engineering and Environmental Laboratory, EG&G Idaho, Idaho Falls, Idaho.

Ebasco Environmental Corporation, 1993, *Final EDF (Tasks 23 and 28) :SDA Ground-Based Geophysics,* Engineering Design File, EDF-WAG7-14, Idaho National Engineering and Environmental Laboratory, Idaho Falls, Idaho.

EG&G, 1981, *Draft Environmental Impact Statement, Long-Term Management of Defense High-Level Radioactive Waste, Idaho Chemical Processing Plant,* DOE/EIS-0074D, Idaho National Engineering and Environmental Laboratory, EG&G Idaho, Idaho Falls, Idaho.

EG&G, 1988, *RCRA Facility Investigation Work Plan,* Vol. 1, EGG-WM-8219, Idaho National Engineering and Environmental Laboratory, EG&G Idaho, Idaho Falls, Idaho.

Greely, R., 1982, "The Style of Basaltic Volcanism in the Eastern Snake River Plain, Idaho," ed. B. Bonnichsen and R. M. Breckenridge, *Cenozoic Geology of Idaho,* Idaho Bureau of Mines and Geology Bulletin.

Hackett, W. R., and R. P. Smith, 1992, "Quaternary Volcanism, Tectonics, and Sedimentation in the Idaho National Engineering Laboratory Area," ed. J. R. Wilson, *Field Guide to Geologic Excursions in Utah and Adjacent Areas of Nevada, Idaho, and Wyoming,* Geological Society of America Rocky Mountain Section Guidebook, Utah Geological Survey Miscellaneous Publication 92-3, pp. 1-18.

Hansen, E. D., 1982, *The Use of Magnesium Chloride for Dust Treatment of Surface Stabilization of Forest Service Roads,* U. S. Department of Agriculture, Forest Service Intermountain Region, Ogden, Utah.

Hem, J. D., 1992, *Study and Interpretation of Chemical Characteristics of Natural Water,* U. S. Geological Survey Water-Supply Paper 2254, U. S. Geological Survey, Reston, Virginia.

Holdren, K. J., B. H. Becker, N. L. Hampton, L. D. Koeppen, S. O. Magnuson, T. J. Meyer, G. L. Olson, and A. J. Sondrup, 2002, *Ancillary Basis for Risk Analysis of the Subsurface Disposal Area,* INEEL/EXT-02-01125, Idaho National Engineering and Environmental Laboratory, Bechtel BWXT Idaho, Idaho Falls, Idaho.

Hubbell, J. M., L. C. Hull, T. G. Humphrey, B. F. Russell, J. R. Pittman, and K. M. Cannon, 1985, *Annual Progress Report: FY-1985—Subsurface Investigation Program at the Radioactive Waste Management Complex of the Idaho National Engineering Laboratory,* DOBID-10136, U. S. Department of Energy Idaho Field Office, Idaho Falls, Idaho.

Hubbell, J. M., L. C. Hull, T. G. Humphrey, B. F. Russell, J. R. Pittman, and P. R. Fischer, 1987, *Annual Progress Report: FY-1986—Subsurface Investigation Program at the Radioactive Waste Management Complex of the Idaho National Engineering Laboratory,* DOEAD-10153, U. S. Department of Energy Idaho Field Office, Idaho Falls, Idaho.

Hubbell, J. M., 1993, *Perched Groundwater Monitoring in the Subsurface Disposal Area of the Radioactive Waste Management Complex,* Engineering Design File EDF ER & WM-EDF002293, Idaho National Engineering and Environmental Laboratory, Lockheed Martin Idaho Technologies Company, Idaho Falls, Idaho.

Hubbell, J. M., 1995, *Perched Groundwater Monitoring in the Subsurface Disposal Area of the Radioactive Waste Management Complex, Idaho, FY-94,* Engineering Design File EDF INEL-95/149, Idaho National Engineering and Environmental Laboratory, Lockheed Martin Idaho Technologies Company, Idaho Falls, Idaho.

Irving, J. S., 1993, *Environmental Resource Document for the Idaho National Engineering Laboratory,* EGG-WMO-10279, Idaho National Engineering and Environmental Laboratory, EG&G Idaho, Idaho Falls, Idaho.

Keating, J., 2001, "Deicing Salt, Still on the Table," *Stormwater,* Vol. 2, 14p.

Keck, K. N., 1995, *SDA Surface Water Description and Data,* Engineering Design File ER-WAG7-66, INEL-951119, Idaho National Engineering and Environmental Laboratory, Lockheed Martin Idaho Technologies Company, Idaho Falls, Idaho.

Kuntz, M. A., B. Skipp, M. A. Lanphere, W. E. Scott, K. L. Pierce, G. B. Dalrymple, D. E. Champion, G. F. Embree, W. R. Page, L. A. Morgan, R. P. Smith, W. R. Hackett, and D. W. Rodgers, 1994, *Geologic Map of the Idaho National Engineering Laboratory and Adjoining Areas, Eastern Idaho,* Miscellaneous Investigation Map, 1-2330, 1:100,000 scale, U.S. Geological Survey.

Laney, P. T., S. C, Minkin, R. G. Baca, D. L. McElroy, J. M. Hubbell, L. C. Hull, B. F. Russell, G. J. Stormberg and J. T. Pittman, 1988, *Annual Progress Report: FY-1987: Subsurface Investigations Program at the Radioactive Waste Management Complex of the Idaho National Engineering Laboratory,* DOE/ID-10183, U. S. Department of Energy Idaho Operations Office, Idaho Falls, Idaho.

Lewis, W. M., 1999, *Studies of Environmental Effects of Magnesium Chloride Deicer in Colorado,* CDOT-DTD-R-99-10, Colorado Department of Transportation, Denver, Colorado.

Magnuson, S. O., and A. J. Sondrup, 1998, *Development, Calibration, and Predictive Results of a Simulator for Subsurface Pathway Fate and Transport of Aqueous- and Gaseous-Phase Contaminants in the Subsurface Disposal Area at the Idaho National Engineering and Environmental Laboratory,* INEEL/EXT-97-00609, Idaho National Engineering and Environmental Laboratory, Lockheed Martin Idaho Technologies Company, Idaho Falls, Idaho.

Martian, P., 1995, *UNSAT-H Infiltration Model Calibration at the Subsurface Disposal Area, Idaho National Engineering Laboratory,* INEL-990596, Idaho National Engineering and Environmental Laboratory, Lockheed Idaho Technologies Company, Idaho Falls, Idaho.

McDaniel, P. A., 1991, *Interpretation of Soil Properties at the RWMC and Spreading Area Sites, Idaho National Engineering Laboratory*, University of Idaho, College of Agriculture, Moscow, Idaho.

McElroy, D. L., 1996, *Subsurface Disposal Area Perched Water Level Data Compilation,* Engineering Design File INEL-96-226, Idaho National Engineering and Environmental Laboratory, Lockheed Martin Idaho Technologies Company, Idaho Falls, Idaho.

National Atmospheric Deposition Program, 2003, http://nadp.sws.uiuc.edu/ (NRSP-3)/National Trends Network, NADP Program Office, Illinois State Water Survey, 2204 Griffith Drive, Champaign, IL 61820.

Nimmo, J. R., K. S. Perkins, P. A. Rose, J. P. Rousseau, B. R. Orr, B. V. Twining, and S. R. Anderson, 2002, "Kilometer-Scale Rapid Transport of Naphthalene Sulfonate Tracer in the Unsaturated Zone at the Idaho National Engineering and Environmental Laboratory," *Vadose Zone Journal,* Vol. 1, pp. 89-101.

Piciulo, P. L., C. E. Shea, and R. E. Barletta, 1985, *Analysis of Soils From the Low-Level Radioactive Waste Disposal Sites at Bamwell, SC, and Richland, WA,* NUREG/CR-4083, Nuclear Regulatory Commission, Washington, DC.

Porro, I., and C. W. Bishop, 1995, *Large-Scale Infiltration Test, CPM Data Analysis,* Engineering Design File ER-WAG7-58, INEL-95/040, Idaho National Engineering and Environmental Laboratory, Lockheed Martin Idaho Technologies Company, Idaho Falls, Idaho.

Rawson, S. A., J. C. Walton, and R. G. Baca, 1991, "Migration of Actinides from a Transuranic Waste Disposal Site in the Vadose Zone," *Radiochim. Acta,* Vol. 52-53, p. 477-486.

Rhoades, J. D., 1982, "Soluble Salts," in: *Methods of Soil Analysis Part 2: Chemical and Microbiological Properties,* A. L. Page, R. H. Miller, and D. R. Keeney (ed), Soil Science Society of America, Inc., Madison, WI, pp. 167-179.

Ritter, P. D., and D. L. McElroy, 1999, *Progress Report: Tritium and Carbon-14 Sampling at the Radioactive Waste Management Complex,* INEEL/EXT-98-00669, Idaho National Engineering and Environmental Laboratory, Bechtel BWXT Idaho, LLC, Idaho Falls, Idaho.

Roberge, P. R., 2000, *Handbook of Corrosion Engineering,* McGraw-Hill, New York, New York.

Shaw, P. G., 1992, *Sampling Pad A Nitrate Salt Drum,* Engineering Design File EDF-ERD-BWP-78, EG&G Idaho, Inc., Idaho Falls, Idaho.

Skorseth, K., 2000, *Gravel Roads, Maintenance and Design Manual,* South Dakota Local Transportation Assistance Program, South Dakota State University, Brookings, South Dakota.

Transportation Research Board, 1991, *Highway Deicing, Comparing Salt and Calcium Magnesium Acetate,* Committee on the Comparative Cost of Rock Salt and Calcium Magnesium Acetate for Highway Deicing, Special Report 235, National Research Council, Washington, DC.

Wegner, W., and M. Yaggi, 2001, "Environmental Impacts of Road Salt and Alternatives in the New York City Watershed," *Stormwater,* 2, 13p.

Appendix A

Suction Lysimeters Installed at the Radioactive Waste Management Complex.

Appendix A

Suction Lysimeters Installed at the Radioactive Waste Management Complex

Lysimeter	Well	Date Installed	Lysimeter Depth (m)	Lithology or stratigraphy	Cup Type
L01	W02[a]	June 14,1985	4.27	Surf. Sediment	Ceramic
L02	W03	June 17,1985	3.20	Surf. Sediment	Ceramic
L03	W04	June 19,1985	7.47	Surf. Sediment	Ceramic
L04	W04	June 19,1985	4.69	Surf. Sediment	Ceramic
L05	W04	June 19,1985	1.89	Surf. Sediment	Ceramic
L06	w20	June 28,1985	2.04	Surf. Sediment	Teflon
L07	W23	June 28,1985	5.73	Surf. Sediment	Teflon
L08	W23	June 28, 1985	3.60	Surf. Sediment	Ceramic
L09	W23	June 28,1985	2.35	Surf. Sediment	Ceramic
L10	T23	July 2, 1985	5.79	Surf. Sediment	Teflon
L11	c02	July 3, 1985	1.31	Surf. Sediment	Teflon
L12	W08	July 9, 1985	6.74	Surf. Sediment	Ceramic
L13	W08	July 9, 1985	3.44	Surf. Sediment	Ceramic
L14	W08	July 9, 1985	1.89	Surf. Sediment	Ceramic
L15	PA01[b]	July 11, 1985	4.36	Surf. Sediment	Ceramic
L16	PA02[b]	July 11, 1985	2.65	Surf. Sediment	Ceramic
L17	TH02	June 7,1985	1.83	Surf. Sediment	Ceramic
L18	TH04	April 23,1985	1.22	Surf. Sediment	Ceramic
L19	CO1	August 6, 1986	5.39	Surf. Sediment	Ceramic
L20	CO1	August 6, 1986	2.26	Surf. Sediment	Ceramic
L21	TH05	September 8, 1986	4.63	Surf. Sediment	Ceramic
L22	TH05	September 8, 1986	1.80	Surf. Sediment	Ceramic
L23	W09	September 17, 1986	4.5 1	Surf. Sediment	Ceramic
L24	W05	September 22, 1986	4.85	Surf. Sediment	Ceramic
L25	W05	September 22, 1986	3.05	Surf. Sediment	Ceramic
L26	W05	September 22, 1986	2.04	Surf. Sediment	Ceramic
L27	W06	September 23, 1986	3.60	Surf. Sediment	Ceramic
L28	W25	September 24, 1986	4.72	Surf. Sediment	Ceramic
L29	W13	September 20, 1986	4.27	Surf. Sediment	Ceramic
L30	W13	September 28, 1986	2.04	Surf. Sediment	Ceramic
L31	W 17	September 29, 1986	5.97	Surf. Sediment	Ceramic
L32	W17	September 29, 1986	3.32	Surf. Sediment	Ceramic

Lysimeter	Well	Date Installed	Lysimeter Depth (m)	Lithology or stratigraphy	Cup Type
L33	PA03[b]	December 1994	3.05	Surf. Sediment	Ceramic
L34	PA04[b]	December 1994	−8.25	Surf. Sediment	Ceramic
L35	98-1	February 2, 1998	5.03	Surf. Sediment	Ceramic
L36	98-2	January 29, 1998	2.74	Surf. Sediment	Ceramic
L37	98-3	February 4, 1998	6.86	Surf. Sediment	Ceramic
L38	98-4	February 3, 1998	5.18	Surf. Sediment	Ceramic
L39	98-5	February 2,1998	3.20	**Surf.** Sediment	Ceramic
L40	LYS-1	1994	2.00	Surf. Sediment	Ceramic
L41	LYS-1	1994	6.00	Surf. Sediment	Ceramic
DLO1	D06	September 12, 1986	26.8	Basalt	Ceramic
DL02	D06	September 12, 1986	13.4	AB interbed, silty sand	Ceramic
DL03	TW1	June 25,1987	69.2	0.3 m into CD interbed, clay	Ceramic
DL04	TW1	June 25, 1987	31.0	Top of BC interbed, sandy silt	Ceramic
DL05	D15	September 15,1987	67.9	Top **of** CD interbed, clay and silt	Ceramic
DL06	D15	September 15,1987	29.8	BC interbed, gravel	Ceramic
DL07	D15	November 4, 1987	9.8	Top of AB interbed, sandy sit.	Ceramic
DL08	I-1D	−November 1999	68.3	Basalt / CD interbed contact	Stainless steel
DL09	I-1S	−November 1999	31.8	At BC contact or < 0.3 m into BC	Stainless steel
DL10	I-2D	−November 1999	59.7	Basalt above CD interbed	Stainless steel
DL11	1-2s	−November 1999	28.0	Basalt above BC interbed	Stainless steel
DL12	I-3D	−November 1999	69.5	at CD contact or < 1 m into CD	Stainless steel
DL13	I-3S	−November 1999	28.4	0.67 m into BC interbed, clay	Stainless steel
DL14	I-4D	−January 2000	69.0	Basalt 0.5 m above CD interbed	Stainless steel

Lysimeter	Well	Date Installed	Lysimeter Depth (m)	Lithology or stratigraphy	Cup Type
DL15	I-4S	−January 2000	29.6	Basalt, 15 cm above BC interbed	Stainless steel
DL16	I-5S	~March 2000	30.1	Basalt, 0.3 m above BC interbed	Stainless steel
DL17	O-1	December 16, 1999	69.5	Near top CD interbed, no recovery 221-233	Stainless steel
DL18	O-1	December 16,1999	29.3	0.6 m into BC interbed, clay	Stainless steel
DL19	0-2	January 12,2000	73.2	Basalt	Stainless steel
DL20	0-2	January 12, 2000	32.3	Basalt, 0.3 m above BC interbed	Stainless steel
DL21	0-3	November 1999	66.7	Basalt, 0.6 m above CD interbed	Stainless steel
DL22	0-3	November 1999	26.5	Basalt	Stainless steel
DL23	O-4	January 4,2000	68.6	Basalt / CD interbed contact	Stainless steel
DL24	O-4	January 4,2000	33.1	1.2 m into BC interbed, gravel	Stainless steel
DL25	0-5	January 12,2000	31.7	Basalt	Stainless steel
DL26	0-6	November 1999	68.6	Basalt	Stainless steel
DL27	0-7	November 1999	73.2	Basalt, rubble	Stainless steel
DL28	0-7	November 1999	36.3	Basalt, 0.3 m above BC interbed	Stainless steel
DL29	0-8	−November 1999	69.5	Basalt	Stainless steel

a. Lysimeters LOl and W02 were destroyed in 1993 during the construction phase of Pit 9 remediation activities.
b. Boreholes PA-01 and PA-02 were located in surficial sediment a couple of feet off the edge of the Pad A asphalt pad. The lithologic log for Borehole PA-03 does not indicate augering through the asphalt pad. The lysimeter in Borehole PA-04 was installed under the asphalt pad.

Appendix B

**Physical and Chemical Characteristics of Representative
Water Samples from the Shallow and Intermediate Depths in
the Vadose Zone at the SDA**

Table B-1. Sample location, date, field parameters, and errors in cation-anion balance for representative water sample collected from lysimeters at the **SDA.**

Well	Lysimeter	Depth (ft bls)	Depth (m bls)	Date	Lab pH	Field pH	Calc pH	Temp (C)	TDS (mg/L)	Cations (meq/L)	Anions (meq/L)	Error
Brine	Brine								517,939	10,491	10,612	-0.6%
Shallow	Vadose	Zone										
98-1	98-1L35	16.5	5.0	9/8/98	7.7	—	6.50	—	16,282	280.0	305.8	-4.4%
98-4	98-4L38	17.0	5.2	9/8/98	7.1	—	7.04	15.0	704	9.6	11.8	-10.3%
98-5	98-5L39	10.5	3.2	9/8/98	7.6	6.5	6.93	15.5	1,571	21.3	26.5	-10.8%
C01	C01-L19	17.7	5.4	8/29/89	7.9	7.4	7.92	11.4	744	10.3	10.3	-0.1%
C01	C01-L20	7.4	2.3	6/21/88	8.2	7.8	7.84	12.5	681	10.3	10.1	0.9%
PAO1	PA01-L15	14.3	4.4	9/27/88	7.7	7.7	6.85	15.5	3,044	38.4	39.8	-1.8%
PAO1	PA01-L15	14.3	4.4	9/27/95	7.3	—	7.35	15.0	1,818	23.3	24.6	-2.7%
PAO1	PA01-L15	14.3	4.4	9/8/98	7.5	—	7.40	17.0	1,806	22.3	25.5	-6.7%
PA02	PA02-L16	8.7	2.7	9/27/88	—	7.5	6.68	19.0	3,966	56.2	56.2	0.0%
TH04	TH04-L18	4.0	1.2	6/11/86	7.4	—	6.88	15.0	9,333	171.3	165.6	1.7%
TH05	TH05-L21	15.2	4.6	9/14/87	—	8.0	7.32	14.6	729	9.2	9.6	-2.0%
w02	wo2-LO1	14.0	4.3	7/26/89	7.6	7.7	7.34	15.7	910	11.8	11.7	0.4%
W03	W03-LO2	10.5	3.2	7/27/89	7.6	7.6	6.45	14.6	23,541	434.0	416.4	2.1%
W04	W04-LO3	24.5	7.5	10/3/89	7.4	7.3	6.83	14.9	1,886	23.6	22.8	1.7%
W04	W04-LO4	15.4	4.7	9/30/88	7.4	—	6.64	—	1,712	21.1	21.2	0.0%
W04	W04-LO5	6.2	1.9	6/11/86	—	—	6.68	—	1,330	19.3	19.2	0.3%
W05	W05-L24	15.9	4.8	10/3/89	7.7	7.3	7.25	15.7	2,075	30.7	30.2	0.8%
W05	W05-L25	10.0	3.0	7/24/89	—	—	6.57	—	21,242	390.3	382.0	1.1%
W05	W05-L26	6.7	2.0	7/20/89	8.1	—	6.89	12.0	13,094	233.9	226.9	1.5%
W06	W06-L27	11.8	3.6	7/20/89	7.4	7.3	7.58	14.4	1,073	13.8	13.7	0.3%
W08	W08-L12	22.1	6.7	8/28/89	8.0	6.9	7.09	16.6	1,885	26.6	26.5	0.1%
W08	W08-L12	22.1	6.7	9/27/95	7.1	7.0	7.21	15.6	1,640	23.2	25.8	-5.4%
W08	W08-L13	11.3	3.4	10/2/89	7.7	—	6.91	—	1,994	27.7	27.3	0.7%
W09	W09-L23	14.8	4.5	9/27/88	7.8	7.9	7.10	15.0	832	11.4	11.6	-0.7%

Table B-1. (continued).

Well	Lysimeter	Depth (ft bls)	Depth (m bls)	Date	Lab pH	Field pH	Calc pH	Temp (C)	TDS (mg/L)	Cations (meq/L)	Anions (meq/L)	Error
W09	W09-L23	14.8	4.5	8/28/89	8.1	7.7	7.15	16.1	917	12.6	13.1	-1.9%
W23	W23-LO8	11.8	3.6	10/4/89	—	—	6.81	14.8	5,822	91.4	88.7	1.5%
W23	W23-LO8	11.8	3.6	9/26/95	7.0	7.1	7.04	14.5	5,662	80.5	100.7	-11.1%
W23	W23-LO8	11.8	3.6	9/8/98	7.7		6.88	—	4,027	54.1	68.5	-11.8%
W23	W23-LO9	7.7	2.3	6/11/86	8.1	7.7	7.26	13.2	3,392	52.7	52.0	0.7%
W23	W23-LO9	7.7	2.3	9/8/98		7.6	7.43	18.5	1,836	22.3	26.5	-8.7%
W25	W25-L28	15.5	4.7	10/5/89	7.7	7.2	7.13	12.4	770	11.0	10.6	2.1%
W25	W25-L28	15.5	4.7	9/8/98	7.4	—	6.94	—	811	11.5	17.3	-20.2%
Intermed.	Vadose			Zone								
D06	D06-DL01	88.0	26.8	9/9/98	7.5	—	6.71	—	7,758	115.1	141.4	-10.3%
D06	D06-DL02	44.0	13.4	7/27/89	7.7	7.5	6.93	18.9	13,039	226.1	219.9	1.4%
D15	D15-DL06	97.9	29.8	9/27/88	8.2	7.6	7.80	12.0	965	13.5	13.7	-0.9%
TW1	TW1-DL04	101.7	31.0	6/16/88	7.8	7.9	6.89	15.1	5,745	101.3	100.3	0.5%

Table **B-2.** Cation concentrations of representative water samples from lysimeters in the shallow and intermediate depths of the vadose zone at the **SDA.**

Well	Lysimeter	Date	Li (mg/L)	Na (mg/L)	K (mg/L)	Mg (mg/L)	Ca (mg/L)	Sr (mg/L)	Ba (mg/L)	Mn (mg/L)	Fe (mg/L)
Brine		Brine	2,500	11,200	8,400	114,530	120				
98-1	98-1L35	9/8/98	0.16	2090	11.3	1290	1650	13.3	—	—	—
98-4	98-4L38	9/8/98	0.02	36.3	3.61	32.2	105	0.62	—	—	—
98-5	98-5L39	9/8/98	0.03	253	6.5	45	128	0.89	—	—	—
C01	C01-L19	8/29/89	< .04	150	2.32	16.4	46.8	0.27	< .31	< .24	0.08
C01	C01-L20	6/21/88	< .04	33.7	2.95	37.9	111	1	< .31	< .24	< .02
PAOl	PA01-L15	9/27/88	< .04	732	4.32	41.6	58.8	0.54	< .31	< .24	< .02
PAOl	PA01-L15	9/27/95	—	470	2.62	18.8	24.5	—	—	0.01	0.32
PA01	PA01-L15	9/8/98	0.02	455	2.55	17.2	20.6	—	—	—	—
PA02	PA02-L16	9/27/88	0.19	821	8.36	119	208	1.51	< .31	< .24	< .02
THO4	TH04-L18	6/11/86	0.11	1360	9.46	1047	513	5.95	< .31	< .24	< .02
TH05	TH05-L21	9/14/87	< .04	106	5.1	16.2	61.6	0.35	< .31	< .24	< .02
w02	wo2-LO1	7/26/89	< .04	188	1.45	15.4	46	0.35	< .31	< .24	< .02
W03	WO3-LO2	7/27/89	0.13	3912	27.2	1699	2463	18.2	0.89	< .24	0.07
W04	WO4-LO3	10/3/89	0.08	415	3.14	25.4	66.6	0.48	< .31	< .24	< .02
W04	WO4-LO4	9/30/88	0.06	306	3.52	46.5	77.5	0.72	< .31	< .24	< .02
W04	WO4-LO5	6/11/86	0.06	117	2.81	95.3	125	1.28	< .31	< .24	0.04
W05	W05-L24	10/3/89	< .04	456	3.81	66.4	105	0.72	< .31	< .24	< .02
W05	W05-L25	7/24/89	0.15	2956	14.8	1903	2090	16	0.64	< .24	0.17
W05	W05-L26	7/20/89	0.1	2564	11	925	915	11	< .31	< .24	0.06
W06	W06-L27	7/20/89	< .04	262	2.56	13.8	23.1	0.18	< .31	< .24	0.05
W08	W08-L12	8/28/89	0.05	414	4.98	54.9	77.6	0.73	0.39	< .24	c .02
W08	WO8-L12	9/27/95	—	338	75.4	43.6	58.9		0.13	0.002	0.09
W08	W08-L13	10/2/89	0.08	349	17.6	85.8	99	1.06	< .31	< .24	< .02
W09	W09-L23	9/27/88	< .04	43.9	4.81	51.3	102	0.89	0.32	< .24	< .02
W09	W09-L23	8/28/89	< .04	50.4	3.82	57.1	112	1	0.38	< .24	0.06

Table B-2. (continued).

Well	Lysimeter	Date	Li (mg/L)	Na (mg/L)	K (mg/L)	Mg (mg/L)	Ca (mg/L)	Sr (mg/L)	Ba (mg/L)	Mn (mg/L)	Fe (mg/L)
W23	W23-LO8	10/4/89	0.05	1501	11.1	103	347	1.53	< .31	< .24	< .02
W23	W23-LO8	9/26/95	—	1320	9.9	90.5	309	—	0.02	0.005	0.06
W23	W23-LO8	9/8/98	0.05	945	7.91	54	167	0.82	—	—	—
W23	W23-LO9	6/11/86	0.1	965	6.74	73.3	88.3	1.08	< .31	< .24	< .02
W23	W23-LO9	9/8/98	0.05	463	4.55	12.3	19.8	0.28			
W25	W25-L28	10/5/89	< .04	30.6	4.8	49.2	110	1.06	< .31	< .24	< .02
W25	W25-L28	9/8/98	0.02	31	4.48	50.5	117	1.11	—	—	—
D06	D06-DL01	9/9/98	0.22	1020	43.5	426	691	2.69	—	—	—
D06	D06-DL02	7/27/89	0.15	2937	61.5	735	724	5.08	< .31	< .24	0.05
D15	D15-DL06	9/27/88	0.07	256	4.05	5.53	35.2	0.29	< .31	< .24	< .02
TW1	TW1-DL04	6/16/88	0.18	595	29.7	417	804	3.58	0.4	2.19	0.03

Table **B-3.** Anion and neutral species concentrations of representative water samples from lysimeters in the shallow and intermediate depths of the vadose zone at the SDA.

Well	Lysimeter	Date	HC03 (mg/L)	F (mg/L)	Cl (mg/L)	Br (mg/L)	SO4 (mg/L)	N03-N (mg/L)	Al (mg/L)	SI02 (mg/L)	B (mg/L)
Brine		Brine	384		356,240	765	26,300				
98-1	98-1L35	9/8/98	237	—	9490	17	1440	57	—	—	—
98-4	98-4L38	9/8/98	410	—	25	<.01	42.6	49	—	—	—
98-5	98-5L39	9/8/98	537	—	420	0.86	141	40	—	—	—
C01	C01-L19	8/29/89	170	1	8	0.5	349	—	<.61	82.8	0.06
C01	C01-L20	6/21/88	87	0.43	22	3.9	382	—	<.61	86	0.14
PAOl	PA01-L15	9/27/88	1754	2.4	205	—	246	—	<.61	70	1.79
PAOl	PA01-L15	9/27/95	1070	5.3	135	0.34	70.4	20.8	—	—	—
PAOl	PA01-L15	9/8/98	1050	—	171	0.5	57.5	32	—	—	—
PA02	PA02-L 16	9/27/88	945	0.75	252	1.4	1610	—	<.61	101	0.07
THO4	THO4-L18	6/11/86	363	0.4	4507	10	1510	13	<.61	74.5	0.22
TH05	TH05-L21	9/14/87	388	0.73	1.4	—	150	—	<.61	72.8	<.05
w02	wo2-LO1	7/26/89	499	0.18	27	—	133	—	<.61	76	0.13
W03	W03-LO2	7/27/89	289	0.3	13030	—	2120	—	<.61	74	0.27
W04	W04-LO3	10/3/89	1330	0.71	4.7	—	40	—	<.61	75.4	0.19
W04	W04-LO4	9/30/88	1244	1.35	2.7	—	30	—	<.61	79.2	0.25
W04	W04-LO5	6/11/86	720	0.5	134	—	120	15	<.61	77.2	<.05
W05	W05-L24	10/3/89	414	0.44	269	1	759	—	<.61	76.5	<.05
W05	W05-L25	7/24/89	192	0.28	11600	19.2	2467	—	<.61	70.8	1.03
W05	W05-L26	7/20/89	242	1.45	6403	10.5	2022	—	<.61	77.5	1.75
W06	W06-L27	7/20/89	610	1.21	42	—	118	—	<.61	73.3	0.57
W08	W08-L12	8/28/89	684	0.7	238	—	411	—	<.61	76.2	0.7
W08	W08-L12	9/27/95	624	1.2	262	0.28	174	62.9	—	—	—
W08	W08-L13	10/2/89	699	1.1	45	—	697	—	<.61	84.8	0.48
W09	W09-L23	9/27/88	412	0.2	34	—	184	—	<.61	81.5	0.11
W09	W09-L23	8/28/89	350	0.26	31	0.9	312	—	<.61	80.9	0.11

Table **B-3.** (continued).

Well	Lysimeter	Date	HC03 (mg/L)	F (mg/L)	Cl (mg/L)	**Br** (mg/L)	SO4 (mg/L)	N03-N (mg/L)	Al (mg/L)	SI02 (mg/L)	B (mg/L)
W23	W23-LO8	10/4/89	532	0.72	1444	2.9	1880	—	< .61	86.7	0.96
W23	W23-LO8	9/26/95	339	2.8	1720	10.6	1710	150	—	—	—
W23	W23-LO8	9/8/98	571	—	936	1.7	1250	94	—	—	—
W23	W23-LO9	6/11/86	587	0.8	803	1.1	836	31	< .61	78.1	0.16
W23	W23-LO9	9/8/98	1039	—	73.5	< .13	170	54	—	—	—
W25	W25-L28	10/5/89	380	0.44	36	—	159	—	< .61	81.6	< .05
W25	W25-L28	9/8/98	364	—	92.8	< .13	41.5	110	—	—	—
D06	D06-DL01	9/9/98	264	—	3420	8.4	1860	24.8	—	—	—
D06	D06-DL02	7/27/89	229	0.4	5730	10.5	2612	—	< .61	76.9	0.24
D15	D15-DL06	9/27/88	278	0.9	152	—	233	—	< .61	83.5	< .05
TW1	TW1-DL04	6/16/88	182	0.53	2700	—	1017	—	< .61	79.6	0.15

Table B-4. Mineral saturation indecies calculated using PHREEQC for representative water samples from lysimeters in the shallow and intermediate depths of the vadose zone at the **SDA.**

Well	Lysimeter	Date	Calcite Sat Index	Dolomite Sat Index	Siderite Sat Index	Gypsum Sat Index	Celestite Sat Index	Barite Sat Index	Fluorite Sat Index	Chalcedony Sat Index	Quartz Sat Index	log $P_{CO2(g)}$
Brine	Brine		0									
98-1	98-1L35	9/8/98	0	0.27	—	-0.21	-0.59	—	—	—	—	-1.36
98-4	98-4L38	9/8/98	0	-0.30	—	-1.88	-2.41	—	—	—	—	-1.52
98-5	98-5L39	9/8/98	0	-0.24	—	-1.42	-1.88	—	—	—	—	-1.30
C01	C01-L19	8/29/89	0	-0.30	-1.36	-1.33	-1.86	1.46	-1.13	0.85	1.33	-2.81
C01	C01-L20	6/21/88	0	-0.30	-2.24	-0.96	-1.31	1.43	-1.53	0.86	1.33	-3.05
PAOl	PA01-L15	9/27/88	0	0.07	-1.53	-1.62	-1.96	I.07	-0.90	0.74	1.20	-0.72
PA0 1	PA0 1-L15	9/27/95	0	0.09	0.01	-2.38	—	—	-0.07	—	—	-1.42
PAOl	PA01-L15	9/8/98	0	0.17	—	-2.54	—	—	—	—	—	-1.46
PA02	PAO2-L16	9/27/88	0	0.03	-1.89	-0.51	-0.94	1.45	-1.68	0.86	1.31	-0.82
THO4	TH04-L18	6/11/86	0	0.54	-2.22	-0.48	-0.71	1.23	-1.93	0.79	1.25	-1.56
TH05	TH05-L21	9/14/87	0	-0.38	-1.45	-1.53	-2.08	1.14	-1.30	0.76	1.22	-1.82
w02	wo2-LO1	7/26/89	0	-0.25	-1.37	-1.73	-2.15	1.06	-2.66	0.77	1.22	-1.72
W03	W03-LO2	7/27/89	0	0.09	-2.38	0.06	-0.37	1.53	-2.25	0.84	1.30	-1.32
W04	W04-LO3	10/3/89	0	-0.20	-1.56	-2.21	-2.65	0.48	-1.81	0.78	1.24	-0.81
W04	W04-LO4	9/30/88	0	0.13	-1.60	-2.31	-2.63	0.15	-1.29	0.67	1.10	-0.59
W04	W04-LO5	6/11/86	0	0.23	-1.41	-1.55	-1.83	0.67	-1.81	0.66	1.09	-0.87
W05	W05-L24	10/3/89	0	0.02	-1.60	-0.91	-1.37	1.43	-1.79	0.77	1.23	-1.75
W05	W05-L25	7/24/89	0	0.35	-1.89	0.01	-0.39	1.24	-2.13	0.69	1.12	-1.57
W05	W05-L26	7/20/89	0	0.19	-1.99	-0.15	-0.36	1.34	-0.70	0.86	1.33	-1.77
W06	W06-L27	7/20/89	0	-0.02	-0.87	-2.08	-2.49	1.04	-1.30	0.77	1.23	-1.88
W08	W08-L12	8/28/89	0	0.09	-1.51	-1.23	-1.56	1.37	-1.52	0.76	1.21	-1.35
W08	W08-L12	9/27/95	0	0.09	-0.77	-1.65	—	0.66	-1.02	—	—	-1.51
W08	W08-L13	10/2/89	0	0.28	-1.60	-0.99	-1.25	1.24	-1.22	0.71	1.13	-1.12
W09	W09-L23	9/27/88	0	-0.09	-1.60	-1.31	-1.67	1.15	-2.29	0.81	1.27	-1.58

Table **B-4.** (continued).

Well	Lysimeter	Date	Calcite Sat Index	Dolomite Sat Index	Siderite Sat Index	Gypsum Sat Index	Celestite Sat Index	Barite Sat Index	Fluorite Sat Index	Chalcedony Sat Index	Quartz Sat Index	log $P_{CO2(g)}$
W09	W09-L23	8/28/89	0	-0.07	-1.15	-1.09	-1.44	1.35	-2.07	0.79	1.25	-1.71
W23	W23-LO8	10/4/89	0	-0.31	-2.06	-0.30	-0.95	1.51	-1.44	0.85	1.31	-1.24
W23	W23-LO8	9/26/95	0	-0.32	-1.51	-0.37	—	0.31	0.11	—	—	-1.67
W23	W23-LO8	9/8/98	0	-0.15	—	-0.68	-1.27	—	—	—	—	-1.20
W23	W23-LO9	6/11/86	0	0.11	-1.54	-1.03	-1.23	1.45	-1.41	0.82	1.28	-1.63
W23	W23-LO9	9/8/98	0	0.06	—	-2.12	-2.26	—	—	—	—	-1.49
W25	W25-L28	10/5/89	0	-0.18	-1.63	-1.33	-1.64	1.14	-1.58	0.84	1.31	-1.66
W25	W25-L28	9/8/98	0	-0.01	—	-1.93	-2.25	—	—	—	—	-1.41
D06	D06-DL01	9/9/98	0	0.14	—	-0.18	-0.88	—	—	—	—	-1.42
D06	D06-DL02	7/27/89	0	0.30	-1.95	-0.15	-0.60	1.30	-1.73	0.77	1.22	-1.78
D15	D15-DL06	9/27/88	0	-0.64	-1.64	-1.62	-2.00	1.32	-1.34	0.85	1.32	-2.47
TW1	TW1-DL04	6/16/88	0	-0.06	-2.21	-0.29	-0.94	1.33	-1.25	0.81	1.27	-1.84

Appendix C

Concentrations of Extractable Soluble Salts in Surficial Sediment Samples Collected from the SDA

Appendix C

Concentrations of Extractable Soluble Salts in Surficial Sediment Samples Collected from the SDA

Table C-1. Extractable ion concentrations for surficial sediment samples collected at the **SDA.**

Well ID	Depth (m)	Cl (mg/kg)	Br (mg/kg)	NO3 (mg/kg)	SO4 (mg/kg)	Ca (mg/kg)	K (mg/kg)	Li (mg/kg)	Mg (mg/kg)	Na (mg/kg)
ACID PIT #4	3.35-3.96	0	0	0	0	12	4	0	4	14
ACIDPIT #4	5.18-5.79	39	1	0	253	71	14	0	20	206
ACIDPIT #4	5.18-5.79	39	1	0	254	75	14	0	21	203
PIT 9 # 5	3.66-4.27	122	1	0	2497	460	0	0	98	656
PIT 9 # 5	5.49-6.10	149	1	0	749	49	9	0	12	490
98-1	1.52	497	2	16	250	204	5	0	44	233
98-1	2.29	278	2	15	24	43	6	0	25	232
98-1	4.57	1703	4	0	534	309	4	0	230	693
98-1	5.49	1112	3	0	477	195	5	0	132	542
SDA-02	1.52	206	3	20	61	73	17	1	65	37
SDA-02	1.83	135	2	14	59	93	20	0	24	120
SDA-02	2.29	152	2	17	55	91	12	0	23	157
SDA-02	4.27	1	0	0	2	22	11	0	13	20
SDA-02	4.42	1	2	1	4	29	9	0	15	35
SDA-02	5.23	1	0	1	4	28	10	0	22	42
SDA-02	5.23	1	0	1	4	27	10	0	22	42
SDA-02	5.33	1	0	1	13	102	10	0	29	52
SDA02	6.10	1	2	0	6	81	3	0	18	49
SDA-03	0.76	7	0	6	6	55	13	0	13	15
SDA-03	1.52	34	2	76	24	40	5	0	38	46
SDA-03	3.05	1	0	23	7	88	8	0	22	20
SDA-03	3.81	0	0	3	8	28	7	0	16	44
98-2	0.76	9	2	36	14	76	6	0	12	45
98-2	1.52	26	2	9	66	156	40	0	17	195
98-2	2.29	198	2	5	164	23	4	0	33	383
SDA-05	1.52	574	0	315	184	150	15	0	54	370
SDA-05	2.29	900	3	541	2898	566	19	0	234	1094
SDA-04	1.52	1035	3	169	137	121	15	0	56	246

Table C-1. (continued).

WellID	Depth (m)	Cl (mg/kg)	Br (mg/kg)	NO3 (mg/kg)	SO4 (mg/kg)	Ca (mg/kg)	K (mg/kg)	Li (mg/kg)	Mg (mg/kg)	Na (mg/kg)
SDA-04	2.29	1167	0	6	709	20	4	0	19	635
SDA-04	3.05	2104	6	1	1273	143	9	0	200	1417
SDA-07	1.52	4	2	2	19	41	3	0	11	16
SDA 07	3.05	15	0	1	9	8	4	0	4	37
SDA-07	4.57	14	0	4	26	40	10	0	18	106
SDA-07	5.33	11	0	1	31	43	12	0	73	54
98-4	1.52	22	0	22	10	61	11	0	7	20
98-4	3.05	2	0	0	1	18	5	0	4	5
98-4	4.57	25	2	5	2	33	10	0	21	25
98-4	4.57	25	2	6	2	40	16	0	58	25
98-4	5.33	3	0	6	2	34	10	0	17	22
98-3	1.52	213	0	15	223	67	13	0	17	152
98-3	2.82	39	2	7	24	35	17	0	14	24
98-3	3.81	16	0	0	6	13	9	0	8	69
98-3	4.88	49	2	6	235	26	14	0	68	149
98-3	6.10	697	2	0	591	75	9	0	18	333
98-3	6.86	486	2	2	394	58	8	0	12	251
98-5	0.76	15	0	0	2	53	7	0	12	10
98-5	1.42	13	0	8	11	75	3	0	9	14
98-5	1.52	6	0	4	7	60	4	0	13	18
98-5	2.29	2	0	1	11	14	4	0	10	36
98-5	3.05	0	0	0	4	6	3	0	4	31
98-5	3.20	8	0	0	13	9	7	0	7	62
98-5	3.20	9	0	0	13	5	3	0	3	56
SDA-11	1.22	2	0	0	2	53	16	0	4	3
SDA-11	2.74	1	0	0	3	19	12	0	12	17
SDA-11	3.96	4	0	0	7	34	16	0	20	29
SDA-12	1.07	1	0	0	2	37	3	0	20	6
SDA-12	1.83	0	0	1	2	25	7	0	26	7
SDA-12	3.35	0	0	9	6	20	13	0	23	76
W05	0.51-1.02	667	2	9	14	286	11	0	50	151
W05	0.51-1.02	677	2	8	14	285	12	0	50	152
W05	1.83-2.34	653	3	0	265	72	6	0	56	503
W05	2.94-3.35	2123	6	0	476	358	12	0	235	971

Table C-1. (continued).

WellID	Depth (m)	Cl (mg/kg)	Br (mg/kg)	NO3 (mg/kg)	SO4 (mglkg)	Ca (mg/kg)	K (mglkg)	Li (mglkg)	Mg (mg/kg)	Na (mg/kg)
W05	3.86-4.37	1343	4	0	374	329	9	0	178	581
SAB #0		0.9	0.0	14	7.6	70	6.1	0.0	15	10
SAB #1		0.4	0.0	6	6.6	72	4.4	0.0	15	9
SAB #2		0.6	0.0	31	6.7	76	6.7	0.0	16	10
SAB #3		0.5	0.0	23	7.0	79	7.6	0.0	15	10
SAB #4		0.6	0.0	31	6.9	79	6.3	0.0	16	10
SAB #5		0.5	0.0	6	7.1	77	7.5	0.0	15	10
SAB #7		0.4	0.0	27	7.1	96	8.0	0.0	17	10
Background"		1.0	0	53	8	103	10	0	18	11

a. Background is calculated from the 8 SAB samples and is the mean + 3 standard deviations.